Joint Effects of Ambient Air Pollutants on Pediatric Asthma Emergency Department Visits in Atlanta, 1998-2004

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Supplemental Material

Model Details

The joint effect models for estimating the joint effects of *p* pollutants, without interactions, had the following form:

$$Log[E(Y)] = \alpha + \sum_{i=1}^{p} \beta_i \, (pollutant)_i \tag{1}$$

$$+ \ \lambda[\log(non - asthma\ pediatric\ resp\ ED\ visits)] + \ g(\gamma_1, \dots, \gamma_N; day\ of\ season)$$

$$+ \ g(\delta_1, \dots, \delta_N; dewpt) + \ g(\eta_1, \dots, \eta_N; min\ temp) + \sum\nolimits_j \xi_j\ (year)_j$$

$$+ \sum\nolimits_k \nu_k (month)_k + \sum\nolimits_l \zeta_l\ (day\ of\ week\ or\ holiday)_l + \sum\nolimits_m \varphi_m\ (hospital)_m$$

$$+ \sum\nolimits_n \tau_n (max\ \ temp\ ℃)_n + \sum\nolimits_{jk} \psi_{jk} (year)_j\ (month)_k$$

$$+ \sum\nolimits_{kn} \omega_{kn}\ (month)_k (\max temp\ ℃)_n$$

$$+ \sum\nolimits_{kl} \vartheta_{kl}\ (month)_k (day\ of\ week\ or\ holiday)_l$$

The dependent variable (Y) was the hospital-specific number of daily pediatric asthma ED visits. Analyses used the three-day moving average of pollutant concentrations (the average of the pollutant concentration on a given day (lag 0) and the previous two days (lags 1 and 2)) (*pollutant)*, which was modeled as a linear term in our primary models. Models included a linear term for the logarithm of the daily number of non-asthma pediatric ED visits for acute upper respiratory infections (*non-asthma pediatric resp ED visits*); cubic polynomials (g) for day-of-season, the moving average of dew point (lags 0-2) (*dewpt*), and the moving average of minimum temperature (lags 1 and 2) (*min temp*); indicator variables for year, month, day of week or holiday (with holidays having a separate indicator), hospital and same-day (lag 0) maximum temperature (for each degree Celsius) (*max temp ℃*); and interaction terms between month and year, month and lag 0 maximum temperature, and month and day of week.

Joint effects were calculated for an interquartile-range (IQR) increment in each pollutant concentration, as the exponentiated sum (across the pollutants in the combination) of the product of each pollutant's model coefficient and that pollutant's IQR, using the following formulas:

$$\boldsymbol{L}'\boldsymbol{\beta} = \sum_{i=1}^{p} \beta_i \, (pollutant\ IQR)_i \tag{2}$$

$$RR_{JE} = \exp[\boldsymbol{L}'\boldsymbol{\beta}] \tag{3}$$

where the joint effect of *p* pollutants (i=1, 2,…,p) is represented by RR_{JE}, β_i is the coefficient for a given pollutant (i) from equation 1 above, **β** is the vector of pollutant parameter estimates, and **L** is the corresponding vector of pollutant IQRs. The 95% confidence interval for the joint effect was calculated (using an "estimate" statement in the SAS "genmod" procedure), according to the following formula:

$$se_{L'\beta} = \sqrt{\boldsymbol{L}'\hat{\boldsymbol{\Sigma}}\boldsymbol{L}} \tag{4}$$

$$95\%\ CI_{RR_{JE}} = (\exp(\boldsymbol{L}'\boldsymbol{\beta} - z_{1-\alpha/2} se_{L'\beta}), \exp(\boldsymbol{L}'\boldsymbol{\beta} + z_{1-\alpha/2} se_{L'\beta})) \tag{5}$$

Where $\hat{\Sigma}$ is the estimated covariance matrix of the estimates and $\alpha = 0.05$.

The joint effect models for estimating the joint effects of *p* pollutants with interactions had the following form:

$$Log[E(Y)] = \alpha + \sum_{i=1}^{p} \beta_i\,(pollutant)_i + \sum_{i=2}^{p}\sum_{q=1}^{i-1} \beta_{iq}\,(pollutant)_i * (pollutant)_q$$
$$+\ \lambda[\log(non-asthma\ pediatric\ resp\ ED\ visits)] +\ g(\gamma_1, \dots, \gamma_N; day\ of\ season)$$
$$+\ g(\delta_1, \dots, \delta_N; dewpt) +\ g(\eta_1, \dots, \eta_N; min\ temp) + \sum\nolimits_j \xi_j\,(year)_j$$
$$+ \sum\nolimits_k \nu_k (month)_k + \sum\nolimits_l \zeta_l\,(day\ of\ week\ or\ holiday)_l + \sum\nolimits_m \varphi_m\,(hospital)_m$$
$$+ \sum\nolimits_n \tau_n (max\ \ temp\ ^\circ\mathrm{C})_n + \sum\nolimits_{jk} \psi_{jk} (year)_j\,(month)_k$$
$$+ \sum\nolimits_{kn} \omega_{kn}\,(month)_k (\max temp\ ^\circ\mathrm{C})_n$$
$$+ \sum\nolimits_{kl} \vartheta_{kl}\,(month)_k (day\ of\ week\ or\ holiday)_l \tag{6}$$

Joint effects for the interaction models were calculated for an increment equal in magnitude to the interquartile-range (IQR) for each pollutant concentration, starting at each pollutant's 15th, 25th, or 35th percentile levels. For joint effects including interactions, the joint effect was calculated as the exponentiated sum (across the pollutants in the combination and their first-order interactions) of 1) the product of each pollutant's model coefficient and that pollutant's IQR, and 2) the product of the coefficient for each interaction term and the difference in the products of the specific pollutant levels being contrasted (represented by a and b in equation 7 below, where b=a+IQR), using the following formulas:

$$\boldsymbol{L}'\boldsymbol{\beta} = \sum_{i=1}^{p} \beta_i\,(pollutant\ IQR)_i + \sum_{i=2}^{p}\sum_{q=1}^{i-1} \beta_{iq}[(b_i * b_q) - (a_i * a_q)] \tag{7}$$

$$RR_{JE} = \exp[\boldsymbol{L}'\boldsymbol{\beta}] \tag{8}$$

where the joint effect of p pollutants (i=1, 2,…,p) is represented by RR_{JE}, β_i is the coefficient for a given pollutant (i) from equation 6 above, β_{iq} is the coefficient for the interaction term for a given pollutant pair, **β** is the vector of parameter estimates including estimates for pollutant s and interaction terms, and **L** is the corresponding vector of pollutant IQRs (for pollutant betas) or differences in the product of contrasted pollutant levels (for interaction term betas). As in the no-interaction model, the 95% confidence interval for the joint effect was calculated (using an "estimate" statement in the SAS "genmod" procedure), according to the following formula:

$$se_{L'\beta} = \sqrt{\boldsymbol{L}'\widehat{\boldsymbol{\Sigma}}\boldsymbol{L}} \tag{9}$$

$$95\%\ CI_{RR_{JE}} = (\exp(\boldsymbol{L}'\boldsymbol{\beta} - z_{1-\alpha/2}se_{L'\beta}), \exp(\boldsymbol{L}'\boldsymbol{\beta} + z_{1-\alpha/2}se_{L'\beta})) \tag{10}$$

Where $\hat{\Sigma}$ is the estimated covariance matrix of the estimates and $\alpha = 0.05$.

Models used for estimating joint effects that included quadratic and cubic pollutant terms were similar to the model shown in equation 6 above except that quadratic and cubic terms for each pollutant were added to the model rather than interaction terms. The joint effect from these models was calculated as the exponentiated sum (across the pollutants in the combination and their quadratic and cubic terms) of 1) the product of each pollutant's model coefficient and that pollutant's IQR, and 2) the product of the coefficient for each quadratic and cubic term and the corresponding difference in the squared or cubed pollutant values for the specific pollutant levels being contrasted, in a manner similar to that shown in equation 7 above.

eTable 1. Percentage of warm and cold season days with all pollutants in various quartiles of their respective year-round distributions,[a] Atlanta, 1998-2004

Combination	Season	All Quartile 1	All Quartile 2	All Quartile 3	All Quartile 4	All not in same quartile
Oxidant Gases (O_3, NO_2, SO_2)	WARM	3.6%	1.3%	1.3%	4.8%	89.0%
Secondary (O_3, Secondary $PM_{2.5}$[b])	WARM	3.7%	5.4%	9.4%	26.4%	55.1%
Traffic (CO, NO_2, EC)	WARM	11.5%	4.6%	4.2%	10.5%	69.2%
Power Plant (SO_2, SO_4^{2-})	WARM	4.9%	4.7%	7.0%	11.2%	72.2%
Criteria Pollutants (O_3, CO, NO_2, SO_2, $PM_{2.5}$)	WARM	1.8%	0.4%	0.5%	2.6%	94.7%
Oxidant Gases (O_3, NO_2, SO_2)	COLD	4.5%	1.2%	2.0%	1.1%	91.2%
Secondary (O_3, Secondary $PM_{2.5}$[b])	COLD	14.4%	9.0%	5.6%	1.5%	69.5%
Traffic (CO, NO_2, EC)	COLD	9.1%	2.3%	3.0%	13.8%	71.8%
Power Plant (SO_2, SO_4^{2-})	COLD	8.4%	6.4%	5.4%	1.9%	77.9%
Criteria Pollutants (O_3, CO, NO_2, SO_2, $PM_{2.5}$)	COLD	1.7%	0.1%	0.2%	0.5%	97.5%

Definition of Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter less than 2.5 µm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-} =sulfate component of $PM_{2.5}$.

[a] Frequencies are calculated for percentage of warm or cold season days on which the various daily pollutant values were in various quartiles of the overall-year daily pollutant distribution.

[b] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of selected $PM_{2.5}$ components including sulfate, nitrate, and ammonium.

eTable 2. Primary joint effect model effect estimates, Atlanta, 1998-2004, calculated for an inter-quartile range[a] change in the 3-day moving average of each pollutant

Effect	Season	Model Specifications	Joint Effect Estimate RR (95% CI)	Joint Effect Estimate p-value	Interaction p-value[b]
Oxidant Gases (O_3, NO_2, SO_2)	WARM	Model including only pollutants in joint effect, no interactions	1.0981 (1.0440-1.1550)	0.0003	NA
		Model including only pollutants in joint effect, with first order interactions	1.0997 (1.0432-1.1593)	0.0004	0.9748
Secondary (O_3, Secondary $PM_{2.5}$[c])	WARM	Model including only pollutants in joint effect, no interactions	1.0851 (1.0354-1.1372)	0.0006	NA
		Model including only pollutants in joint effect, with first order interactions	1.0853 (1.0281-1.1457)	0.0031	0.9900
Traffic (CO, NO_2, EC)	WARM	Model including only pollutants in joint effect, no interactions	1.1108 (1.0621-1.1616)	<0.0001	NA
		Model including only pollutants in joint effect, with first order interactions	1.1332 (1.0768-1.1924)	<0.0001	0.4209
Power Plant (SO_2, SO_4^{2-})	WARM	Model including only pollutants in joint effect, no interactions	1.0574 (1.0211-1.0950)	0.0018	NA
		Model including only pollutants in joint effect, with first order interactions	1.0829 (1.0374-1.1304)	0.0003	0.0598
Criteria Pollutants (O_3, CO, NO_2, SO_2, $PM_{2.5}$)	WARM	Model including only pollutants in joint effect, no interactions	1.1289 (1.0573-1.2053)	0.0003	NA
		Model including only pollutants in joint effect, with first order interactions	1.1540 (1.0698-1.2449)	0.0002	0.3314
Oxidant Gases (O_3, NO_2, SO_2)	COLD	Model including only pollutants in joint effect, no interactions	1.0539 (0.9851-1.1275)	0.1274	NA
		Model including only pollutants in joint effect, with first order interactions	1.0307 (0.9548-1.1126)	0.4386	0.0088
Secondary (O_3, Secondary $PM_{2.5}$[c])	COLD	Model including only pollutants in joint effect, no interactions	1.0617 (0.9918-1.1366)	0.0850	NA
		Model including only pollutants in joint effect, with first order interactions	1.0457 (0.9745-1.1222)	0.2138	0.0890
Traffic (CO, NO_2, EC)	COLD	Model including only pollutants in joint effect, no interactions	1.0194 (0.9896-1.0500)	0.2045	NA
		Model including only pollutants in joint effect, with first order interactions	1.0182 (0.9799-1.0579)	0.3565	0.9941
Power Plant (SO_2, SO_4^{2-})	COLD	Model including only pollutants in joint effect, no interactions	0.9810 (0.9398-1.0240)	0.3803	NA
		Model including only pollutants in joint effect, with first order interactions	0.9845 (0.9428-1.0280)	0.4788	0.2658
Criteria Pollutants (O_3, CO, NO_2, SO_2, $PM_{2.5}$)	COLD	Model including only pollutants in joint effect, no interactions	1.0397 (0.9670-1.1178)	0.2926	NA
		Model including only pollutants in joint effect, with first order interactions	0.9943 (0.9026-1.0953)	0.9077	0.0002

Definition of Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter less than 2.5 µm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$, RR=Rate Ratio

[a] For comparability with previous analyses,[1] the analysis used the year-round IQR during 1993-2004 for O_3, NO_2, CO and SO_2, and during August 1, 1998-December 31, 2004 for $PM_{2.5}$ and $PM_{2.5}$ components. The IQRs used in the analysis were: O_3 29.18 ppb, CO 0.66 ppm, NO_2 12.87 ppb, SO_2 10.51 ppb, $PM_{2.5}$ 9.18 µg/m^3, EC 0.69 µg/m^3, SO_4^{2-} 3.45 µg/m^3, Secondary $PM_{2.5}$ 4.52 µg/m^3, NO_x 42.70 ppb.

[b] Interaction test was a likelihood ratio test, testing the hypothesis that the coefficients for all interaction terms equal 0, performed using a contrast statement in SAS PROC GENMOD.

[c] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of selected $PM_{2.5}$ components including sulfate, nitrate, and ammonium.

eTable 3. Single-pollutant model effect estimates, Atlanta, warm and cold seasons , 1998-2004, calculated for an inter-quartile range[a] change in the 3-day moving average of in each pollutant

Effect	Season	Model Specifications	Effect Estimate	
			RR (95% CI)	p-value
O_3	WARM	Single Pollutant Model	1.0778 (1.0308-1.1270)	0.0010
CO	WARM	Single Pollutant Model	1.1076 (1.0597-1.1576)	0.0000
NO_2	WARM	Single Pollutant Model	1.0868 (1.0536-1.1211)	0.0000
SO_2	WARM	Single Pollutant Model	1.0426 (1.0112-1.0750)	0.0074
$PM_{2.5}$	WARM	Single Pollutant Model	1.0430 (1.0165-1.0703)	0.0014
EC	WARM	Single Pollutant Model	1.0401 (1.0097-1.0714)	0.0095
SO_4^{2-}	WARM	Single Pollutant Model	1.0261 (1.0041-1.0487)	0.0200
Secondary $PM_{2.5}$[b]	WARM	Single Pollutant Model	1.0263 (1.0049-1.0481)	0.0159
O_3	COLD	Single Pollutant Model	1.0702 (1.0079-1.1364)	0.0266
CO	COLD	Single Pollutant Model	1.0150 (0.9869-1.0439)	0.2993
NO_2	COLD	Single Pollutant Model	1.0193 (0.9917-1.0478)	0.1723
SO_2	COLD	Single Pollutant Model	0.9841 (0.9578-1.0111)	0.2446
$PM_{2.5}$	COLD	Single Pollutant Model	1.0045 (0.9785-1.0311)	0.7372
EC	COLD	Single Pollutant Model	1.0032 (0.9814-1.0254)	0.7787
SO_4^{2-}	COLD	Single Pollutant Model	0.9907 (0.9538-1.0290)	0.6306
Secondary $PM_{2.5}$[b]	COLD	Single Pollutant Model	0.9840 (0.9530-1.0160)	0.3221

Definition of Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter less than 2.5 µm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$, RR=Rate Ratio

[a] For comparability with previous analyses,[1] the analysis used the year-round IQR during 1993-2004 for O_3, NO_2, CO and SO_2, and during August 1, 1998-December 31, 2004 for $PM_{2.5}$ and $PM_{2.5}$ components. The IQRs used in the analysis were: O_3 29.18 ppb, CO 0.66 ppm, NO_2 12.87 ppb, SO_2 10.51 ppb, $PM_{2.5}$ 9.18 µg/m^3, EC 0.69 µg/m^3, SO_4^{2-} 3.45 µg/m^3, Secondary $PM_{2.5}$ 4.52 µg/m^3.

[b] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of selected $PM_{2.5}$ components including sulfate, nitrate, and ammonium.

eTable 4. Pollutant-specific parameter and concurvity estimates, primary models, Atlanta, 1998-2004, Warm Season

Effect	Model Specifications	Pollutant*	Unit	Coefficient per 1 unit change	p-value	Concurvity: all variables	Concurvity: pollutants only
O_3	Single Pollutant Model	O_3	ppb	0.0026	0.0010	0.874	NA
CO	Single Pollutant Model	CO	ppm	0.1548	0.0000	0.841	NA
NO_2	Single Pollutant Model	NO_2	ppb	0.0065	0.0000	0.812	NA
SO_2	Single Pollutant Model	SO_2	ppb	0.0040	0.0074	0.609	NA
$PM_{2.5}$	Single Pollutant Model	$PM_{2.5}$	μg/m^3	0.0046	0.0014	0.734	NA
EC	Single Pollutant Model	EC	μg/m^3	0.0569	0.0095	0.825	NA
SO_4^{2-}	Single Pollutant Model	SO_4^{2-}	μg/m^3	0.0075	0.0200	0.726	NA
Secondary $PM_{2.5}$ [a]	Single Pollutant Model	Secondary $PM_{2.5}$ [a]	μg/m^3	0.0057	0.0159	0.727	NA
Oxidant Gases	Model including only pollutants in joint effect, no interactions	O_3	ppb	0.0003	0.7949	0.923	0.566
		NO_2	ppb	0.0059	0.0004	0.901	0.646
		SO_2	ppb	0.0010	0.5495	0.686	0.443
	Model including only pollutants in joint effect, with first order interactions	O_3	ppb	0.0006	0.7216	0.972	0.944
		NO_2	ppb	0.0065	0.1057	0.985	0.972
		SO_2	ppb	-0.0010	0.8756	0.982	0.976
		O_3* NO_2	ppb^2	0.0000	0.7608	0.992	0.986
		O_3* SO_2	ppb^2	0.0000	0.8999	0.986	0.981
		NO_2* SO_2	ppb^2	0.0000	0.7013	0.969	0.957
Secondary	Model including only pollutants in joint effect, no interactions	O_3	ppb	0.0026	0.0091	0.927	0.586
		Secondary $PM_{2.5}$ [a]	μg/m^3	0.0014	0.6247	0.843	0.583
	Model including only pollutants in joint effect, with first order interactions	O_3	ppb	0.0026	0.0621	0.960	0.897
		Secondary $PM_{2.5}$ [a]	μg/m^3	0.0015	0.8375	0.977	0.960
		O_3* Secondary $PM_{2.5}$ [a]	ppb*	0.0000	0.9900	0.987	0.978
Traffic	Model including only pollutants in joint effect, no interactions	CO	ppm	0.1151	0.0377	0.940	0.866
		NO_2	ppb	0.0052	0.0044	0.916	0.777
		EC	μg/m^3	-0.0549	0.0898	0.918	0.839
	Model including only pollutants in joint effect, with first order interactions	CO	ppm	0.1257	0.3404	0.990	0.984
		NO_2	ppb	0.0047	0.2399	0.984	0.973
		EC	μg/m^3	0.0380	0.6552	0.989	0.981
		CO*NO_2	ppm*ppb	0.0017	0.6877	0.996	0.994
		CO*EC	ppm*	-0.0405	0.5716	0.995	0.992
		NO_2*EC	ppb*	-0.0017	0.6214	0.996	0.995
Power Plant	Model including only pollutants in joint effect, no interactions	SO_2	ppb	0.0033	0.0320	0.634	0.256
		SO_4^{2-}	μg/m^3	0.0060	0.0667	0.738	0.261
	Model including only pollutants in joint effect, with first order interactions	SO_2	ppb	0.0099	0.0096	0.950	0.927
		SO_4^{2-}	μg/m^3	0.0150	0.0096	0.927	0.890
		SO_2*SO_4^{2-}	ppb*	-0.0010	0.0602	0.971	0.961
Criteria Pollutants	Model including only pollutants in joint effect, no interactions	O_3	ppb	0.0008	0.5182	0.953	0.792
		CO	ppm	0.0854	0.0909	0.929	0.820
		NO_2	ppb	0.0032	0.1460	0.942	0.864
		SO_2	ppb	0.0007	0.6979	0.693	0.467
		$PM_{2.5}$	μg/m^3	-0.0006	0.7814	0.900	0.767
	Model including only pollutants in joint effect, with first order interactions	O_3	ppb	-0.0034	0.1857	0.989	0.979
		CO	ppm	0.0877	0.5605	0.992	0.988
		NO_2	ppb	0.0099	0.1427	0.995	0.991
		SO_2	ppb	-0.0039	0.5749	0.984	0.978
		$PM_{2.5}$	μg/m^3	0.0012	0.8477	0.990	0.985
		O_3*CO	ppb*ppm	0.0016	0.5689	0.996	0.994
		O_3*NO_2	ppb^2	0.0000	0.7481	0.997	0.996
		O_3*SO_2	ppb^2	0.0002	0.2309	0.993	0.991
		O_3*$PM_{2.5}$	ppb*	0.0001	0.2531	0.996	0.993
		CO*NO_2	ppm*ppb	-0.0061	0.1016	0.994	0.991
		CO*SO_2	ppm*ppb	0.0076	0.2357	0.993	0.991
		CO*$PM_{2.5}$	ppm*	0.0015	0.8420	0.997	0.996
		NO_2*SO_2	ppb^2	0.0002	0.5174	0.995	0.993
		NO_2*$PM_{2.5}$	ppb*	-0.0001	0.7281	0.998	0.997
		SO_2*$PM_{2.5}$	ppb*	-0.0008	0.0361	0.994	0.992

Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter < 2.5 μm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$, ppb=parts per billion, ppm=parts per million, μg/m^3=micrograms per cubic millimeter.

[a] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of the $PM_{2.5}$ components sulfate, nitrate, and ammonium.

eTable 5. Pollutant-specific parameter and concurvity estimates, primary models, Atlanta, 1998-2004, Cold Season

Effect	Model Specifications	Pollutant*	Unit	Coefficient per 1 unit change	p-value	Concurvity: all variables	Concurvity: pollutants only
O_3	Single Pollutant Model	O_3	ppb	0.0023	0.0266	0.905	NA
CO	Single Pollutant Model	CO	ppm	0.0225	0.2993	0.740	NA
NO_2	Single Pollutant Model	NO_2	ppb	0.0015	0.1723	0.740	NA
SO_2	Single Pollutant Model	SO_2	ppb	-0.0015	0.2446	0.721	NA
$PM_{2.5}$	Single Pollutant Model	$PM_{2.5}$	μg/m^3	0.0005	0.7372	0.711	NA
EC	Single Pollutant Model	EC	μg/m^3	0.0046	0.7787	0.776	NA
SO_4^{2-}	Single Pollutant Model	SO_4^{2-}	μg/m^3	-0.0027	0.6306	0.748	NA
Secondary $PM_{2.5}$ [a]	Single Pollutant Model	Secondary $PM_{2.5}$ [a]	μg/m^3	-0.0036	0.3221	0.700	NA
Oxidant Gases	Model including only pollutants in joint effect, no interactions	O_3	ppb	0.0019	0.0935	0.917	0.398
		NO_2	ppb	0.0012	0.3085	0.790	0.531
		SO_2	ppb	-0.0017	0.2175	0.751	0.422
	Model including only pollutants in joint effect, with first order interactions	O_3	ppb	0.0011	0.6493	0.982	0.965
		NO_2	ppb	0.0006	0.8541	0.976	0.964
		SO_2	ppb	0.0127	0.0059	0.981	0.972
		O_3* NO_2	ppb^2	0.0001	0.1583	0.990	0.985
		O_3* SO_2	ppb^2	-0.0003	0.0222	0.979	0.970
		NO_2* SO_2	ppb^2	-0.0002	0.1463	0.987	0.982
Secondary	Model including only pollutants in joint effect, no interactions	O_3	ppb	0.0026	0.0133	0.908	0.166
		Secondary $PM_{2.5}$ [a]	μg/m^3	-0.0038	0.2877	0.700	0.170
	Model including only pollutants in joint effect, with first order interactions	O_3	ppb	0.0056	0.0059	0.975	0.940
		Secondary $PM_{2.5}$ [a]	μg/m^3	0.0134	0.2135	0.971	0.949
		O_3* Secondary $PM_{2.5}$ [a]	ppb*	-0.0005	0.0894	0.985	0.975
Traffic	Model including only pollutants in joint effect, no interactions	CO	ppm	-0.0074	0.8466	0.920	0.828
		NO_2	ppb	0.0028	0.1410	0.922	0.739
		EC	μg/m^3	-0.0180	0.4414	0.897	0.765
	Model including only pollutants in joint effect, with first order interactions	CO	ppm	0.0154	0.8940	0.992	0.986
		NO_2	ppb	0.0025	0.5478	0.984	0.964
		EC	μg/m^3	-0.0356	0.6753	0.992	0.982
		CO*NO_2	ppm*ppb	-0.0004	0.9117	0.996	0.993
		CO*EC	ppm*	-0.0074	0.9049	0.995	0.992
		NO_2*EC	ppb*	0.0007	0.7813	0.996	0.993
Power Plant	Model including only pollutants in joint effect, no interactions	SO_2	ppb	-0.0013	0.3334	0.746	0.053
		SO_4^{2-}	μg/m^3	-0.0015	0.7984	0.762	0.069
	Model including only pollutants in joint effect, with first order interactions	SO_2	ppb	-0.0042	0.1500	0.950	0.915
		SO_4^{2-}	μg/m^3	-0.0113	0.2841	0.933	0.887
		SO_2*SO_4^{2-}	ppb*	0.0009	0.2654	0.963	0.947
Criteria Pollutants	Model including only pollutants in joint effect, no interactions	O_3	ppb	0.0017	0.1539	0.922	0.456
		CO	ppm	0.0078	0.8306	0.913	0.783
		NO_2	ppb	0.0022	0.2942	0.933	0.815
		SO_2	ppb	-0.0020	0.1536	0.755	0.446
		$PM_{2.5}$	μg/m^3	-0.0024	0.2096	0.838	0.642
	Model including only pollutants in joint effect, with first order interactions	O_3	ppb	-0.0007	0.8073	0.988	0.977
		CO	ppm	0.2354	0.0833	0.994	0.989
		NO_2	ppb	-0.0048	0.4776	0.994	0.990
		SO_2	ppb	0.0093	0.0818	0.985	0.979
		$PM_{2.5}$	μg/m^3	-0.0076	0.2588	0.987	0.981
		O_3*CO	ppb*ppm	-0.0135	0.0000	0.995	0.991
		O_3*NO_2	ppb^2	0.0004	0.0008	0.996	0.993
		O_3*SO_2	ppb^2	-0.0002	0.0425	0.981	0.972
		O_3*$PM_{2.5}$	ppb*	0.0003	0.0814	0.995	0.992
		CO*NO_2	ppm*ppb	0.0089	0.0128	0.996	0.994
		CO*SO_2	ppm*ppb	-0.0081	0.1094	0.990	0.986
		CO*$PM_{2.5}$	ppm*	0.0043	0.5036	0.997	0.994
		NO_2*SO_2	ppb^2	-0.0004	0.1216	0.994	0.992
		NO_2*$PM_{2.5}$	ppb*	-0.0008	0.0199	0.998	0.996
		SO_2*$PM_{2.5}$	ppb*	0.0011	0.0075	0.992	0.989

Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter < 2.5 μm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$, ppb=parts per billion, ppm=parts per million, μg/m^3=micrograms per cubic millimeter.

[a] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of the $PM_{2.5}$ components sulfate, nitrate, and ammonium.

eTable 6. Variance-Covariance matrices for primary joint effect models, Atlanta, 1998-2004, Warm Season

		O_3	CO	NO_2	SO_2	$PM_{2.5}$	EC	SO_4^{2-}	Secondary $PM_{2.5}$ [a]
Oxidant Gases	**O_3**	9.5546E-07		-9.6111E-07	1.6987E-07				
	NO_2	-9.6111E-07		2.7883E-06	-1.0764E-06				
	SO_2	1.6987E-07		-1.0764E-06	2.6953E-06				
Secondary	**O_3**	9.7868E-07							-1.6393E-06
	Secondary $PM_{2.5}$ [a]	-1.6393E-06							8.4099E-06
Traffic	**CO**		3.0670E-03	-4.7960E-05			-8.6823E-04		
	NO_2		-4.7960E-05	3.3395E-06			-1.4614E-05		
	EC		-8.6823E-04	-1.4614E-05			1.0455E-03		
Power Plant	**SO_2**				2.4133E-06			-1.0574E-06	
	SO_4^{2-}				-1.0574E-06			1.0806E-05	
Criteria Pollutants	**O_3**	1.4406E-06	1.6754E-05	-1.1306E-06	1.9821E-07	-1.4534E-06			
	CO	1.6754E-05	2.5525E-03	-6.5342E-05	-3.0834E-06	-2.9971E-05			
	NO_2	-1.1306E-06	-6.5342E-05	4.7764E-06	-1.0238E-06	-1.9850E-07			
	SO_2	1.9821E-07	-3.0834E-06	-1.0238E-06	2.8149E-06	-9.1418E-08			
	$PM_{2.5}$	-1.4534E-06	-2.9971E-05	-1.9850E-07	-9.1418E-08	4.6962E-06			

Definition of Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter less than 2.5 µm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$.

[a] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of selected $PM_{2.5}$ components including nitrate (NO_3^-), ammonium (NH_4^+), and sulfate (SO_4^{2-}).

eTable 7. Variance-Covariance matrices for primary joint effect models, Atlanta, 1998-2004, Cold Season

		O_3	CO	NO_2	SO_2	$PM_{2.5}$	EC	SO_4^{2-}	Secondary $PM_{2.5}$ [a]
Oxidant Gases	**O_3**	1.2486E-06		-4.5664E-07	2.4593E-07				
	NO_2	-4.5664E-07		1.4460E-06	-4.9985E-07				
	SO_2	2.4593E-07		-4.9985E-07	1.9131E-06				
Secondary	**O_3**	1.1417E-06							-1.1427E-07
	Secondary $PM_{2.5}$ [a]	-1.1427E-07							1.3045E-05
Traffic	**CO**		1.4512E-03	-4.5887E-05			-2.7387E-04		
	NO_2		-4.5887E-05	3.7117E-06			-1.4109E-05		
	EC		-2.7387E-04	-1.4109E-05			5.4888E-04		
Power Plant	**SO_2**				1.9323E-06			-1.7643E-06	
	SO_4^{2-}				-1.7643E-06			3.3063E-05	
Criteria Pollutants	**O_3**	1.3608E-06	5.3877E-06	-7.1054E-07	2.3490E-07	1.2589E-08			
	CO	5.3877E-06	1.3210E-03	-5.3425E-05	-1.1995E-06	-2.2904E-06			
	NO_2	-7.1054E-07	-5.3425E-05	4.4393E-06	-5.2562E-07	-1.5992E-06			
	SO_2	2.3490E-07	-1.1995E-06	-5.2562E-07	2.0331E-06	9.1886E-08			
	$PM_{2.5}$	1.2589E-08	-2.2904E-06	-1.5992E-06	9.1886E-08	3.5909E-06			

Definition of Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter less than 2.5 µm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$.

[a] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of selected $PM_{2.5}$ components including nitrate (NO_3^-), ammonium (NH_4^+), and sulfate (SO_4^{2-}).

eTable 8. Sensitivity analyses for joint effect calculations, Atlanta, 1998-2004, calculated for an inter-quartile range[a] change in the 3-day moving average of in each pollutant

Effect	Season	Model Specifications	Joint Effect Estimate[b] RR (95% CI)	Joint Effect Estimate[b] p-value	Interaction or Non-linear term p-value[c]
Oxidant Gases (O_3, NO_2, SO_2)	WARM	Model including pollutants in joint effect, also controlling for CO and $PM_{2.5}$, no interactions	1.0729 (0.9990-1.1522)	0.0531	NA
		Model including only pollutants in joint effect, with linear, quadratic and cubic terms for each pollutant	1.0957 (1.0297-1.1658)	0.0039	0.8487
Secondary (O_3, Secondary $PM_{2.5}$[d])	WARM	Model including pollutants in joint effect, also controlling for CO, NO_2, and SO_2, no interactions	1.0206 (0.9628-1.0820)	0.4929	NA
		Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	1.0855 (1.0233-1.1514)	0.0064	0.7532
Traffic (CO, NO_2, EC)	WARM	Model including pollutants in joint effect, also controlling for O3, SO2 and SO_4^{2-}, no interactions	1.1113 (1.0523-1.1735)	0.0001	NA
		Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	1.0900 (1.0279-1.1559)	0.0040	0.0262
Power Plant (SO_2, SO_4^{2-})	WARM	Model including pollutants in joint effect, also controlling for O3, CO, NO_2 and EC, no interactions	1.0033 (0.9613-1.0472)	0.8802	NA
		Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	1.0634 (1.0060-1.1240)	0.0299	0.7920
Criteria Pollutants (O_3, CO, NO_2, SO_2, $PM_{2.5}$)	WARM	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	1.1149 (1.0322-1.2041)	0.0056	0.8846
Oxidant Gases (O_3, NO_2, SO_2)	COLD	Model including pollutants in joint effect, also controlling for CO and $PM_{2.5}$, no interactions	1.0572 (0.9778-1.143)	0.1628	NA
		Model including only pollutants in joint effect, with linear, quadratic and cubic terms for each pollutant	1.1323 (1.0324-1.2418)	0.0084	0.1948
Secondary (O_3, Secondary $PM_{2.5}$[d])	COLD	Model including pollutants in joint effect, also controlling for CO, NO_2, and SO_2, no interactions	1.0333 (0.9574-1.1153)	0.3999	NA
		Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	1.1852 (1.0877-1.2914)	0.0001	0.0004
Traffic (CO, NO_2, EC)	COLD	Model including pollutants in joint effect, also controlling for O3, SO2 and SO_4^{2-}, no interactions	1.0242 (0.9912-1.0584)	0.1525	NA
		Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	1.0076 (0.9665-1.0505)	0.7216	0.9279
Power Plant (SO_2, SO_4^{2-})	COLD	Model including pollutants in joint effect, also controlling for O3, CO, NO_2 and EC, no interactions	0.9583 (0.9145-1.0042)	0.0743	NA
		Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	1.0258 (0.9727-1.0818)	0.3468	0.0118
Criteria Pollutants (O_3, CO, NO_2, SO_2, $PM_{2.5}$)	COLD	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	1.1322 (1.0252-1.2503)	0.0142	0.0295

Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter < 2.5 µm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$, RR=Rate Ratio

[a] For comparability with previous analyses,[1] the analysis used the year-round IQR during 1993-2004 for O_3, NO_2, CO and SO_2, and during August 1, 1998-December 31, 2004 for $PM_{2.5}$ and $PM_{2.5}$ components. The IQRs used in the analysis were: O_3 29.18 ppb, CO 0.66 ppm, NO_2 12.87 ppb, SO_2 10.51 ppb, $PM_{2.5}$ 9.18 µg/m^3, EC 0.69 µg/m^3, SO_4^{2-} 3.45 µg/m^3, Secondary $PM_{2.5}$ 4.52 µg/m^3, NO_x 42.7 ppb, RR=Rate Ratio

[b] In interaction models, the joint effects were calculated for an IQR change from the 25th percentile level to the 75th percentile level for each pollutant.

[c] The test for the interaction terms and non-linear terms (quadratic and cubic terms) was a likelihood ratio test, testing the hypothesis that the coefficients for all interaction terms, or all quadratic and cubic terms, equal 0, performed using a contrast statement in SAS PROC GENMOD.

[d] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of the $PM_{2.5}$ components sulfate, nitrate, and ammonium.

eTable 9. Pollutant-specific parameter estimates from sensitivity analyses, Atlanta, 1998-2004, Warm Season

Joint Effect	Model Specifications	Pollutant[a]	Unit	Coefficient per 1 unit change	p-value
Oxidant Gases	Model including pollutants in joint effect, also controlling for CO and $PM_{2.5}$, no interactions	O_3	ppb	0.0008	0.5182
		CO	ppm	0.0854	0.0909
		NO_2	ppb	0.0032	0.1460
		SO_2	ppb	0.0007	0.6979
		$PM_{2.5}$	μg/m³	-0.0006	0.7814
	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	O_3	ppb	-0.0096	0.1990
		$(O_3)^2$	ppb²	0.0002	0.2043
		$(O_3)^3$	ppb³	0.0000	0.2376
		NO_2	ppb	0.0143	0.2540
		$(NO_2)^2$	ppb²	-0.0003	0.5968
		$(NO_2)^3$	ppb³	0.0000	0.6912
		SO_2	ppb	-0.0030	0.6781
		$(SO_2)^2$	ppb²	0.0002	0.6257
		$(SO_2)^3$	ppb³	0.0000	0.6899
Secondary	Model including pollutants in joint effect, also controlling for CO, NO_2, and SO_2, no interactions	O_3	ppb	0.0006	0.5886
		CO	ppm	0.0895	0.0754
		NO_2	ppb	0.0039	0.0859
		SO_2	ppb	0.0001	0.9460
		Secondary $PM_{2.5}$ [b]	μg/m³	0.0005	0.8704
	Model including only pollutants in joint effect, with linear, quadratic and cubic terms for each pollutant	O_3	ppb	-0.0074	0.3461
		$(O_3)^2$	ppb²	0.0002	0.2095
		$(O_3)^3$	ppb³	0.0000	0.2360
		Secondary $PM_{2.5}$ [b]	μg/m³	0.0033	0.8755
		(Secondary $PM_{2.5})^2$ [b]	(μg/m³)²	-0.0004	0.8110
		(Secondary $PM_{2.5})^3$ [b]	(μg/m³)³	0.0000	0.7255
Traffic	Model including pollutants in joint effect, also controlling for O_3, SO_2 and SO_4^{2-}, no interactions	O_3	ppb	0.0008	0.4801
		CO	ppm	0.1179	0.0430
		NO_2	ppb	0.0041	0.0706
		SO_2	ppb	0.0001	0.9468
		EC	μg/m³	-0.0369	0.3133
		SO_4^{2-}	μg/m³	0.0006	0.8823
	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	CO	ppm	0.7011	0.0347
		$(CO)^2$	ppm²	-0.5832	0.0520
		$(CO)^3$	ppm³	0.1580	0.0466
		NO_2	ppb	0.0155	0.2502
		$(NO_2)^2$	ppb²	-0.0005	0.3825
		$(NO_2)^3$	ppb³	0.0000	0.3589
		EC	μg/m³	-0.2653	0.0611
		$(EC)^2$	(μg/m³)²	0.2277	0.0243
		$(EC)^3$	(μg/m³)³	-0.0572	0.0057
Power Plant	Model including pollutants in joint effect , also controlling for O_3, CO, NO_2 and EC, no interactions	O_3	ppb	0.0008	0.4801
		CO	ppm	0.1179	0.0430
		NO_2	ppb	0.0041	0.0706
		SO_2	ppb	0.0001	0.9468
		EC	μg/m³	-0.0369	0.3133
		SO_4^{2-}	μg/m³	0.0006	0.8823
	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	SO_2	ppb	0.0104	0.1276
		$(SO_2)^2$	ppb²	-0.0004	0.3559
		$(SO_2)^3$	ppb³	0.0000	0.4906
		SO_4^{2-}	μg/m³	0.0101	0.6992
		$(SO_4^{2-})^2$	(μg/m³)²	-0.0008	0.8132
		$(SO_4^{2-})^3$	(μg/m³)³	0.0000	0.7686
Criteria Pollutants	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	O_3	ppb	-0.0072	0.3505
		$(O_3)^2$	ppb²	0.0002	0.3141
		$(O_3)^3$	ppb³	0.0000	0.3600
		CO	ppm	0.5136	0.1138
		$(CO)^2$	ppm²	-0.3857	0.1950
		$(CO)^3$	ppm³	0.1036	0.2096
		NO_2	ppb	0.0081	0.5549
		$(NO_2)^2$	ppb²	-0.0002	0.7217
		$(NO_2)^3$	ppb³	0.0000	0.7645
		SO_2	ppb	-0.0009	0.9020
		$(SO_2)^2$	ppb²	0.0001	0.7966
		$(SO_2)^3$	ppb³	0.0000	0.7096
		$PM_{2.5}$	μg/m³	-0.0089	0.6576
		$(PM_{2.5})^2$	(μg/m³)²	0.0003	0.7950
		$(PM_{2.5})^3$	(μg/m³)³	0.0000	0.8969

Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter < 2.5 μm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$, ppb=parts per billion, ppm=parts per million, μg/m³=micrograms per cubic millimeter.

[a] Shaded pollutants were not included in calculation of joint effect.

[b] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of the $PM_{2.5}$ components sulfate, nitrate, and ammonium.

eTable 10. Pollutant-specific parameter estimates from sensitivity analyses, Atlanta, 1998-2004, Cold Season

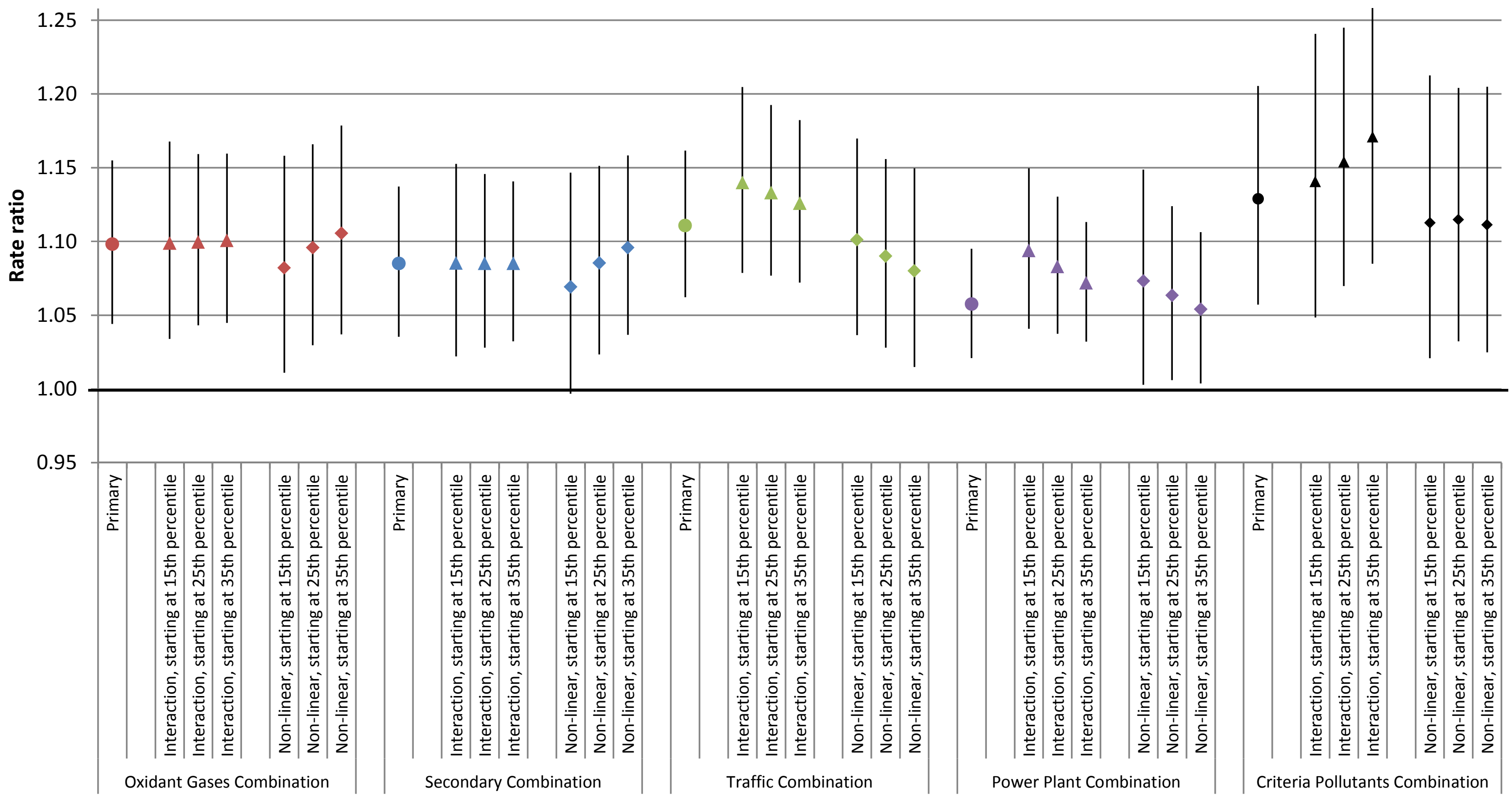
Joint Effect	Model Specifications	Pollutant[a]	Unit	Coefficient per unit change	p-value
Oxidant Gases	Model including pollutants in joint effect, also controlling for CO and $PM_{2.5}$, no interactions	O_3	ppb	0.0017	0.1539
		CO	ppm	0.0078	0.8306
		NO_2	ppb	0.0022	0.2942
		SO_2	ppb	-0.0020	0.1536
		$PM_{2.5}$	μg/m³	-0.0024	0.2096
	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	O_3	ppb	-0.0160	0.0491
		$(O_3)^2$	ppb²	0.0004	0.0579
		$(O_3)^3$	ppb³	0.0000	0.1302
		NO_2	ppb	-0.0046	0.7993
		$(NO_2)^2$	ppb²	0.0002	0.7776
		$(NO_2)^3$	ppb³	0.0000	0.7914
		SO_2	ppb	0.0060	0.4683
		$(SO_2)^2$	ppb²	-0.0005	0.3280
		$(SO_2)^3$	ppb³	0.0000	0.3088
Secondary	Model including pollutants in joint effect, also controlling for CO, NO_2, and SO_2, no interactions	O_3	ppb	0.0021	0.0789
		CO	ppm	-0.0025	0.9464
		NO_2	ppb	0.0023	0.2570
		SO_2	ppb	-0.0018	0.2255
		Secondary $PM_{2.5}$ [b]	μg/m³	-0.0061	0.1194
	Model including only pollutants in joint effect, with linear, quadratic and cubic terms for each pollutant	O_3	ppb	-0.0183	0.0228
		$(O_3)^2$	ppb²	0.0005	0.0226
		$(O_3)^3$	ppb³	0.0000	0.0656
		Secondary $PM_{2.5}$ [b]	μg/m³	-0.0306	0.2433
		(Secondary $PM_{2.5}$)² [b]	(μg/m³)²	0.0047	0.1341
		(Secondary $PM_{2.5}$)³ [b]	(μg/m³)³	-0.0002	0.0410
Traffic	Model including pollutants in joint effect, also controlling for O_3, SO_2 and SO_4^{2-}, no interactions	O_3	ppb	0.0022	0.0633
		CO	ppm	-0.0062	0.8736
		NO_2	ppb	0.0021	0.3260
		SO_2	ppb	-0.0017	0.2607
		EC	μg/m³	0.0021	0.9319
		SO_4^{2-}	μg/m³	-0.0072	0.2392
	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	CO	ppm	0.2945	0.2740
		$(CO)^2$	ppm²	-0.2698	0.2277
		$(CO)^3$	ppm³	0.0703	0.2183
		NO_2	ppb	-0.0104	0.5815
		$(NO_2)^2$	ppb²	0.0004	0.5013
		$(NO_2)^3$	ppb³	0.0000	0.5332
		EC	μg/m³	-0.0730	0.4805
		$(EC)^2$	(μg/m³)²	0.0327	0.5735
		$(EC)^3$	(μg/m³)³	-0.0046	0.6078
Power Plant	Model including pollutants in joint effect , also controlling for O_3, CO, NO_2 and EC, no interactions	O_3	ppb	0.0022	0.0633
		CO	ppm	-0.0062	0.8736
		NO_2	ppb	0.0021	0.3260
		SO_2	ppb	-0.0017	0.2607
		EC	μg/m³	0.0021	0.9319
		SO_4^{2-}	μg/m³	-0.0072	0.2392
	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	SO_2	ppb	0.0100	0.2223
		$(SO_2)^2$	ppb²	-0.0008	0.1487
		$(SO_2)^3$	ppb³	0.0000	0.1641
		SO_4^{2-}	μg/m³	-0.0404	0.2318
		$(SO_4^{2-})^2$	(μg/m³)²	0.0109	0.0846
		$(SO_4^{2-})^3$	(μg/m³)³	-0.0007	0.0225
Criteria Pollutants	Model including only pollutants in joint effects, with linear, quadratic and cubic terms for each pollutant	O_3	ppb	-0.0172	0.0362
		$(O_3)^2$	ppb²	0.0005	0.0428
		$(O_3)^3$	ppb³	0.0000	0.0917
		CO	ppm	0.3685	0.1537
		$(CO)^2$	ppm²	-0.3269	0.1305
		$(CO)^3$	ppm³	0.0838	0.1326
		NO_2	ppb	-0.0132	0.4931
		$(NO_2)^2$	ppb²	0.0005	0.4662
		$(NO_2)^3$	ppb³	0.0000	0.5101
		SO_2	ppb	0.0114	0.1800
		$(SO_2)^2$	ppb²	-0.0010	0.0935
		$(SO_2)^3$	ppb³	0.0000	0.0847
		$PM_{2.5}$	μg/m³	-0.0253	0.0625
		$(PM_{2.5})^2$	(μg/m³)²	0.0013	0.0374
		$(PM_{2.5})^3$	(μg/m³)³	0.0000	0.0168

Abbreviations: O_3=ozone, CO=carbon monoxide, NO_2=nitrogen dioxide, SO_2=sulfur dioxide, $PM_{2.5}$=particulate matter < 2.5 μm in diameter, EC=elemental carbon component of $PM_{2.5}$, SO_4^{2-}=sulfate component of $PM_{2.5}$, ppb=parts per billion, ppm=parts per million, μg/m³=micrograms per cubic millimeter.

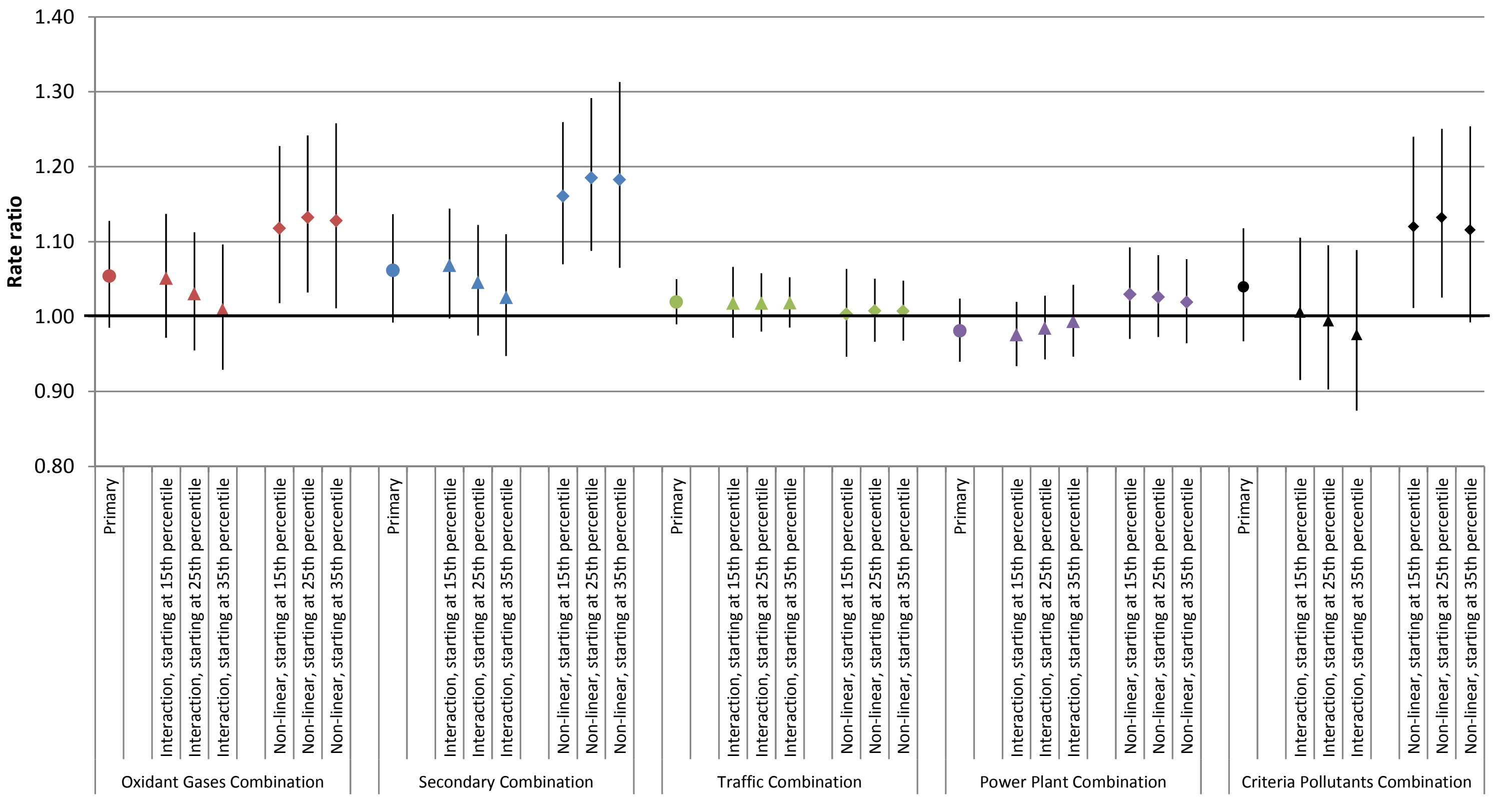
[a] Shaded pollutants were not included in calculation of joint effect.

[b] Secondary $PM_{2.5}$ was calculated as the sum of the concentrations of the $PM_{2.5}$ components sulfate, nitrate, and ammonium.

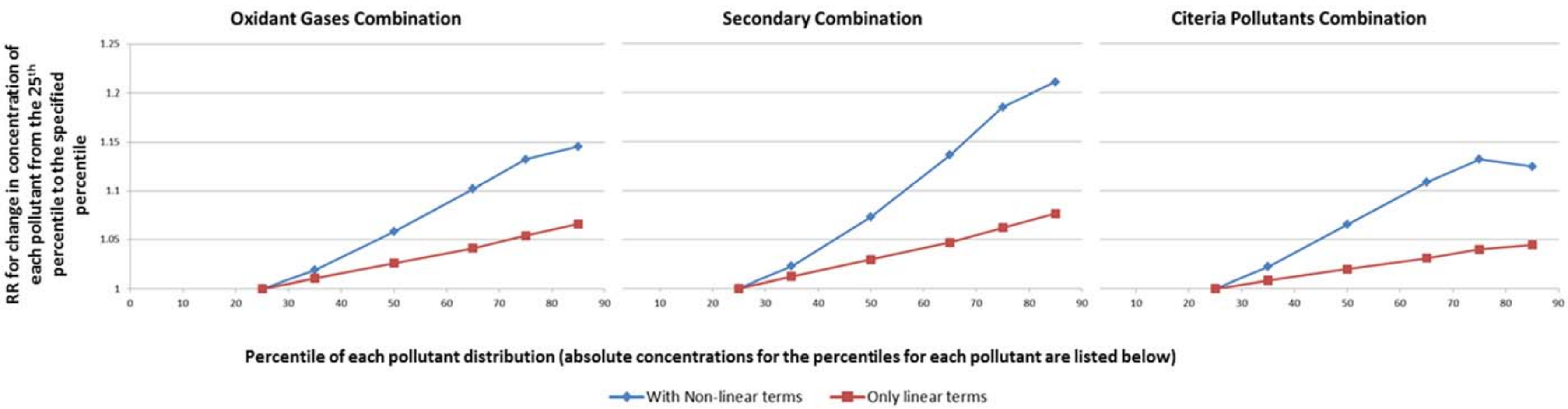
eFigure 1. Rate ratios for joint effects from multipollutant models, evaluated for various specific IQR increments in each pollutant, Warm Season. Rate ratios are shown in red for the oxidant pollutant combination, blue for the secondary pollutant combination, green for the traffic pollutant combination, purple for the power plant pollutant combination, and black for the criteria pollutant combination. For each combination of pollutants, joint effect rate ratios from the primary multipollutant models, which had linear pollutant terms and no interactions ("Primary", circle markers), are followed by multipollutant models with linear pollutant terms and first order interactions between pollutants, with IQR changes evaluated starting at the 15^{th}, 25^{th}, and 35^{th} percentiles for each pollutant ("Interaction", triangle markers); and multipollutant models with linear, quadratic and cubic pollutant terms and no interactions, with IQR changes evaluated starting at the 15^{th}, 25^{th}, and 35^{th} percentiles for each pollutant ("Non-linear", diamond markers). For comparability with previous analyses,[1] the analysis used the year-round IQR during 1993-2004 for O_3, NO_2, CO and SO_2, and during August 1, 1998-December 31, 2004 for $PM_{2.5}$ and $PM_{2.5}$ components. The IQRs used in the analysis were: O_3 29.18 ppb, CO 0.66 ppm, NO_2 12.87 ppb, SO_2 10.51 ppb, $PM_{2.5}$ 9.18 µg/m3, EC 0.69 µg/m3, SO_4^{2-} 3.45 µg/m3, Secondary $PM_{2.5}$ 4.52 µg/m3.



eFigure 2. Rate ratios for joint effects from multipollutant models, evaluated for various specific IQR increments in each pollutant, Cold Season. Rate ratios are shown in red for the oxidant pollutant combination, blue for the secondary pollutant combination, green for the traffic pollutant combination, purple for the power plant pollutant combination, and black for the criteria pollutant combination. For each combination of pollutants, joint effect rate ratios from the primary multipollutant models, which had linear pollutant terms and no interactions ("Primary", circle markers), are followed by multipollutant models with linear pollutant terms and first order interactions between pollutants, with IQR changes evaluated starting at the 15th, 25th, and 35th percentiles for each pollutant ("Interaction", triangle markers); and multipollutant models with linear, quadratic and cubic pollutant terms and no interactions, with IQR changes evaluated starting at the 15th, 25th, and 35th percentiles for each pollutant ("Non-linear", diamond markers). For comparability with previous analyses,[1] the analysis used the year-round IQR during 1993-2004 for O_3, NO_2, CO and SO_2, and during August 1, 1998-December 31, 2004 for $PM_{2.5}$ and $PM_{2.5}$ components. The IQRs used in the analysis were: O_3 29.18 ppb, CO 0.66 ppm, NO_2 12.87 ppb, SO_2 10.51 ppb, $PM_{2.5}$ 9.18 µg/m3, EC 0.69 µg/m3, SO_4^{2-} 3.45 µg/m3, Secondary $PM_{2.5}$ 4.52 µg/m3.



eFigure 3. Rate ratios per changes in the concentration of each pollutant from the 25th percentile to various specified percentiles based on results of joint effect models with and without non-linear terms (quadratic and cubic pollutant terms), for selected pollutant combinations, Atlanta, 1998-2004, cold season.



	Percentile	25	35	50	65	75	85	25	35	50	65	75	85	25	35	50	65	75	85
Absolute pollutant concentrations*	O3 (ppb)	30.10	35.44	43.55	52.02	59.27	67.44	30.10	35.44	43.55	52.02	59.27	67.44	30.10	35.44	43.55	52.02	59.27	67.44
	CO(ppb)													0.54	0.63	0.78	0.99	1.19	1.45
	NO2 (ppb)	16.29	18.68	22.04	26.04	29.16	32.89							16.29	18.68	22.04	26.04	29.16	32.89
	SO2 (ppb)	4.03	5.49	8.00	11.45	14.54	19.48							4.03	5.49	8.00	11.45	14.54	19.48
	PM2.5 (μg/m³)													10.96	12.53	14.97	17.71	20.14	24.01
	Secondary PM (μg/m³)							4.26	4.91	6.05	7.48	8.77	10.82						

*For comparability with previous analyses,[1] the percentiles were based on the year-round distribution during 1993-2004 for O3, NO2, CO and SO2, and during August 1, 1998-December 31, 2004 for PM2.5 and PM2.5 components.

References

1. Strickland MJ, Darrow LA, Klein M, et al. Short-term Associations between Ambient Air Pollutants and Pediatric Asthma Emergency Department Visits. Am J Respir Crit Care Med 2010;182:307-16.